Fact Sheet #4: Functions of Riparian Areas for Fisheries Protection

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[This fact sheet was prepared by Russell Cohen, Rivers Advocate, Riverways Program, Massachusetts Department of Fish and Game. This document is intended for educational purposes only and does not necessarily represent the viewpoint of agencies and commissions having regulatory authority over riparian lands. Date: July 8, 1997.]

What is the significance of riparian areas for fisheries protection?

Naturally vegetated riparian areas perform many beneficial functions for fisheries. These functions may be grouped into the broad categories of habitat creation, water quality, water quantity, and food supply. An example of a water quality function is the shade provided by a streamside forest tree canopy that helps to moderate water temperatures (which is necessary to maintain the relatively high levels of dissolved oxygen needed by trout and other aquatic organisms). An example of a food supply function is the detritus (decomposed vegetative matter) from decaying leaves, twigs, etc. which fall into the stream and provide a key energy source fueling the base of the aquatic food chain. Insects that fall from overhanging trees and shrubs are a particularly important food source for fish in small forested streams.

Habitat creation and food supply: On low-gradient rivers and streams, large woody debris (tree trunks, roots, etc.) falling and/or extending out into the water add structure to the stream, providing needed cover for fish to hide from predators and prey. On smaller and/or higher-gradient rivers and streams, large woody debris helps to create the "pool-riffle" habitat that is essential for many fish species and many aquatic insects they depend upon for food. A pool is an area of deep, slow water; a riffle is an area of shallow, swift water. Pools provide cover, shelter and resting areas for sportfish. Riffles reaerate the water, produce most of the fishes' food, and are used as spawning and feeding areas. Fish expend considerable energy maintaining their positions when feeding in riffles. Nearby pools serve as resting and hiding areas as well as important refuges during low-flow periods. Nearly all streamfish require clean gravel to spawn and larger cobbles or boulders for resting and cover. The smaller fine bottom materials (silt and clay) generally are unsuitable for spawning sites since they smother eggs and young fish.

Water Quantity: Riparian forests can minimize disruption of aquatic communities by maintaining streamflow during droughts and reducing streambank erosion and other adverse impacts of flood events. Fish can actually get evicted from their in-stream habitats by floods that can literally wash them out as well as alter the pools, riffles, etc. that they call home. Streamside forests reduce the quantity and velocity of flood flows both by storing and absorbing flood waters in the floodplain and by contributing debris to the stream that absorbs the force of flood flows and gives fish a place of shelter to resist being swept downstream. Streamside forests help maintain streamflow in summer so that fish don't lose their habitat by having it dry up on them.

Water Quality: Last but not least, streamside forest areas serve as living biological buffers to absorb excessive levels of sediment, nutrients and other pollutants generated by adjacent development as well as from the stream itself. This function is key to maintaining the high water quality needed by a host of riverine organisms. For example, many benthic macroinvertebrates such as caddis flies and mayflies, both favorite foods for trout, are very sensitive to pollution. Furthermore, streamside forests keep levels of erosion and/or sedimentation below that which would smother the streambottom gravels necessary for successful fish spawning.

What alterations to riparian areas impair their ability to protect fisheries?

Activities within riparian areas that: a) reduce its natural vegetative cover, especially any reduction in streamside forest cover; b) contribute to an excessive level of nutrients or sediments getting into adjacent watercourses; c) involve the use and/or release of heavy metals, pesticides, herbicides and other toxics; or d) increase its imperviousness are likely to result in a degradation of a riparian area's fisheries protection function.

Excess nutrients: Phosphates and nitrates leaching from septic systems or running off fertilized cropland, pastureland, lawns, golf courses and the like, contribute to excessive levels of nutrients in streams, triggering a chain reaction of adverse impacts. Excessive nutrients promote excessive algae and aquatic nuisance weed growth which, in addition to inhibiting the growth of other aquatic vegetation of greater value to aquatic organisms, reduces the level of dissolved oxygen in the water. The resulting hypoxic (low oxygen) or anoxic (zero oxygen) state can cause fish kills and decreases in aquatic insect populations, as well as disruptions in the normal food web and water chemistry balance.

Excessive aquatic weed growth triggered by excess nutrients also has an adverse impact on the quality of the fishing experience. Not only do anglers have to put up with the constant nuisance of weed-choked fishing tackle, canoe paddles and boat propellers, the reduced dissolved oxygen caused by excessive plant growth creates adverse conditions for trout and other highly desirable game fish (which depend on high dissolved oxygen levels) and will eventually result in a shift in species composition toward carp, suckers and other "coarse" fish more highly tolerant of low dissolved oxygen levels. (It should be noted that chemical or mechanical removal of aquatic vegetation from waterways has its own share of adverse impacts and is not a long-term solution nor an effective substitute for reducing excessive nutrient inputs.)

Excessive sedimentation: Sediments carried into streams from sources such as sand washing off from wintertime road sanding operations and silt from tilled cropland and other exposed soils harm fisheries in a number of ways. Excessive sediments increases the water's turbidity (cloudiness) which decreases the transmission of light, which in turn affects plant production. Plant roots anchor the bottom against wave action and disturbance by bottom-feeding fish such as carp. The stems and leaves of floating and emergent plants help to absorb wave energy. When aquatic plant beds are eliminated through excessive sedimentation, turbidity problems may further worsen. Loss of plants also means loss of important fish food like snails and aquatic insects that feed on aquatic plants.

Trout and other fish can tolerate short episodes of high levels of suspended sediment, because they exude a protective mucus on their skin and gills that traps and continually flushes particles away. However, this protective mechanism requires metabolic energy and constitutes a stress on the fish at the same time as its ability to find food is reduced (because of the increasing cloudiness of the water the sediment has caused). Trout and other gamefish rely on relatively clear water to see their prey (and fishermens' lures). In addition to sight feeding, many species of game fish exhibit complex reproductive and social behaviors that depend on visual cues. A reduction in visibility interferes with these visual cues and thereby reduces reproduction success.

Furthermore, excessive sediment fills in the spaces between and beneath pebbles and cobbles on the stream bottom where it can cover up streamside gravel spawning areas and prevent the emergence of recently hatched fish fry. Sediment covering stream gravels also degrades benthic macroinvertebrate habitat. Excessive levels of suspended sediment harms filter-feeding invertebrates who are forced to take in less food (organic particles) and more soil particles. As with excessive nutrients, the long-term effect of excessive sediment and turbidity in rivers is to wipe out suitable habitat for sensitive game species such as trout and replace them with species such as carp and catfish that are tolerant of high turbidity levels and other degraded habitat conditions.

Elevated stream temperatures: One of the most direct adverse impacts of the removal of streamside forests is the resulting increase in stream temperature due to loss of shading. As water temperature increases, its capacity to hold oxygen decreases. Since oxygen is used in the decomposition process, elevated water temperatures reduce a stream's ability to absorb organic matter and assimilate excess nutrients and other pollutants without causing oxygen depletion. Lowered oxygen levels can cause fish mortality and a shift in aquatic community populations. The more desirable "cold-water" species such as trout will be replaced by less desirable "warm-water" fish that can tolerate elevated water temperatures and lowered oxygen levels.

Fish are cold-blooded animals whose body temperatures correlate closely to water temperatures. At warmer temperatures, the fish's metabolic rate speeds up and requires more oxygen at the very time that dissolved oxygen levels in the water are dropping due to the higher temperatures. Removing streamside forests may also alter thermal regimes in a manner that interferes with the thermal cues necessary for successful metamorphosis of aquatic insect species, leaving few larvae or insects for the fish to eat.

The majority of potentially harmful nutrients that enter watercourses are attached to sediment particles. At lower temperatures, the nutrients from excess fertilization of cropland, golf courses, etc. are insoluble and remain attached to these particles. Slight increases in temperature will produce substantial increases in the quantity of elements released into the water, significantly reducing water quality of the stream. In the meantime, these same sediments are themselves likely to increase stream temperature even further (turbid water tends to be warmer than clear water due to increased heat absorption), resulting in additional degradation of habitat for "cold-water" species).

Impervious surfaces: Pavement, roofs and other impervious surfaces are particularly harmful to fisheries. The increasing "flashiness" of runoff from impervious surfaces triggers a cycle of streambank erosion and habitat degradation. A major expression of channel instability is the loss of instream habitat structures, such as the loss of pool and riffle sequences and overhead cover and reduction in the wetted perimeter of the stream, all of which cause a loss in the quality and quantity of suitable habitat conditions for fisheries. Impervious surfaces also collect pollutants deposited from the atmosphere, leaked from vehicles or derived from other sources. During storms, accumulated pollutants are quickly washed off and rapidly delivered to aquatic systems.

Stream temperatures throughout the summer are higher in urban watersheds, and the degree of warming appears to be directly related to the imperviousness of the surrounding watershed. Many studies consistently show that the diversity of benthic macroinvertebrates (a key fish food and an overall indicator of a stream's ecological health) is poor when watershed imperviousness exceeds 10-15%. It is worth noting that these same studies determined that streams flowing through urbanized areas with intact streamside forests had higher benthic macroinvertebrate diversity than those that did not, given the same level of urbanization.

Other pollutants: Heavy metals, a common constituent in runoff from roads, parking lots, roofs and industrial areas bioaccumulates in fish tissues, threatening their health as well as the health of any other animals (including humans) that consume them (thereby dampening the enthusiasm of many recreational anglers). Heavy metals can also affect the reproductive rate and life span of aquatic organisms and hinder photosynthesis in aquatic plants fish rely upon.

Pesticides and herbicides typically get into rivers via runoff or leachate from adjacent farms, yards, golf courses, right-of-way spraying and other highly managed and/or manicured landscapes. These poisons in sufficient toxicity and/or concentration can cause the death of fish and other aquatic and terrestrial organisms. Even at sublethal concentrations, these chemicals can bioaccumulate in fish tissues. As with heavy metals, pesticide residues in fish threatens their health and the health of any other animals and people that consume them. Pesticides also harm other aquatic organisms and aquatic plants fish rely upon.

Last but not least, pathogens (bacteria and viruses) getting into rivers and streams via urban runoff, malfunctioning sewers and septic systems located within riparian areas degrades fisheries by introducing disease-bearing organisms to fish and other aquatic life. The activity of pathogenic organisms also increases with stream temperature, creating a synergistic adverse impact when streamside forests are cleared for development.

Why are vegetated riparian areas along smaller brooks and streams as significant for protecting fisheries as along the larger rivers?

It is especially important from a fisheries protection perspective to preserve corridors of natural vegetation along the smaller brooks and streams. Most of the annual flow in the smaller headwater streams is provided by groundwater (natural spring seeps) that, in turn, is replenished by rainwater falling onto and infiltrating the soil under vegetated areas. Since water seeps slowly through the soil, the surface water flowing in streams can represent rainwater that fell days, weeks or even months ago. This regular, continuous seepage of groundwater that keeps streams flowing is called "baseflow".

Baseflow is critical to stream life and water quality. Low flow periods are typically the most stressful periods for aquatic organisms, resulting in crowding due to less available habitat, elevated water temperatures in the summer and greater freezing in the winter. Sportfish, fish food animals, and water plants require a stable, continuous flow of water, particularly during dry periods. Groundwater discharge is a major source of streamflow for smaller streams, especially during hot and dry summers, where the discharge both augments the streamflow and mitigates harmful temperature increases. This groundwater discharge is key to maintaining adequate water levels and temperatures in streams to support aquatic life.

The failure to maintain vegetative cover on or keep impervious surfaces out of riparian areas adjacent to smaller brooks and streams is likely to result in a significant loss of groundwater recharge and increase the frequency, duration and severity of low flow conditions. In the smaller streams, where flows are already modest in size to begin with, a reduction in baseflow would be especially harmful. Small streams deprived of groundwater flow may even dry up completely, a condition that is obviously extremely stressful if not fatal to fish and other aquatic organisms.

Due to their modest size, small streams and brooks are especially vulnerable to excessive sediment, nutrients and other pollutants, simply because there is a smaller volume of water available to flush out and/or and assimilate these pollutants. All other things being equal, the same development is likely to have a relatively greater negative impact on a small stream's fishery than the same project would along a larger river (the lower water volume in the smaller watercourse will result in higher nonpoint source pollution concentrations). Maintaining a living filter of natural vegetation along smaller brooks and streams both intercepts pollutants before they reach and degrade the sensitive smaller streams as well as enables groundwater recharge and low flow augmentation to help dilute pollutant concentrations.

Because of their small ratio of stream bottom width to shoreline, small headwater streams are especially vulnerable to harmful increases in temperature due to removal of shading from streamside forests. Removal of shading also increases evaporation rates, thereby increasing the duration and frequency of periods where such streams will be too shallow for fish to navigate or even run dry completely, a condition which is obviously harmful if not lethal to fish and other aquatic organisms living there.

Optimum spawning sites for important game fish frequently exist in headwater streams, even though these same fish may spend their remaining time in larger rivers. An increase in water temperature in headwater streams may result in a decrease in fish reproduction. Fortunately, the effectiveness of streamside forest buffers at controlling water temperature increases as stream size decreases. And if water temperatures are kept cool by streamside forests in the upper portion of the watershed, the tributaries will provide a significant beneficial cooling effect on the main watercourses during the summer, when flows are lowest and temperatures are highest.

Studies have shown that streambank forests insulate streams from excessive freezing as well as heating. Excessive freezing can reduce or eliminate the water necessary for fish to survive. The lower streamflow levels combined with ice obstructions creates adverse conditions for fish navigation and other life processes. (Note that water withdrawals from streams during the winter (for snowmaking, e.g.) can have this same effect, as the less water left in the stream, the more vulnerable it is to freezing.) Maintaining deep pools of water as a feature of instream habitat is very important for fish to survive winter conditions, as deeper pools are much more resistant to freezing than are shallower waters.

Even where inaccessible to fish, the small headwater brooks and streams and adjacent riparian areas remaining in a relatively pristine condition provide high levels of water quality and quantity, sediment control, nutrients and woody debris for downstream reaches of the watershed. Thus, especially in the highly degraded systems, headwater streams serve as critical ecological anchors for riverine systems and important refuges for biodiversity. As many of the fisheries in Massachusetts mainstem rivers have already suffered serious degradation, it is the smaller tributary streams, especially the "coldwater" streams capable of supporting naturally reproducing wild trout, where preventing further encroachments into riparian areas is arguably of greatest value from a fisheries perspective.

What are some best managment practices (BMPs) for riparian areas to maintain and enhance their fisheries protection function?

The best way to maximize a riparian area's fisheries protection function is to maintain and/or restore as much of it as possible in an undisturbed, vegetated (preferably forested) state, most importantly at the water's edge. Although a streamside forest at least 80 feet wide on each side of a river or stream is adequate to ensure maximum stream shading, as much of the remainder of the riparian area as possible should be kept in or restored to a naturally vegetated state in order to effectively filter out excess sediments, nutrients and other pollutants before they reach the water, as well as maintain adequate groundwater recharge.

Retaining canopy shade along streams where most of the forest cover has been removed for other land uses is still important. Riparian trees, even in isolated blocks, may still be valuable because stream temperature drops rapidly once a stream reenters a forested riparian area. Studies have shown stream temperatures dropping from 80 to 68 degrees after the stream had flowed through 400 feet of shaded channel.

Logs, stumps and other large woody debris in and/or overhanging the water (even where undercut by the current) should be left undisturbed as much as possible to maximize its value as a food source and instream habitat for fish and other aquatic organisms as well as helping to keep harmful sediment movements under control. Connections between rivers and adjacent floodplains should also be maintained, as floodplains are valuable foraging, spawning and nursery habitat for some fish species. This was dramatically demonstrated during the Great Midwest Flood of 1993 when the Mississippi River reclaimed much of its floodplain. The flood reconnected the river to traditional spawning areas, resulting in a significant increase in fish populations.